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DINÂMICA DE SISTEMAS PARA ANALISAR O CONSUMO DE BIODIESEL E SUA RELAÇÃO COM A EMISSÃO DE CO2 DO TRANSPORTE PÚBLICO EM UM MUNICÍPIO DO RIO GRANDE DO SUL

DYNAMICS OF SYSTEMS TO ANALYZE BIODIESEL CONSUMPTION AND ITS RELATIONSHIP WITH CO2 EMISSIONS FROM PUBLIC TRANSPORTATION IN A MUNICIPALITY OF RIO GRANDE DO SUL

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Resumo:. Este trabalho apresenta a compreensão, desenvolvimento e execução de um modelo computacional, cuja principal funcionalidade é analisar a quantidade de emissões de CO2 relacionadas ao transporte público em uma cidade do Rio Grande do Sul, onde três cenários foram gerados com diferentes percentuais de Biodiesel somados a diesel mineral. Para o desenvolvimento do modelo, foi utilizado o método System Dynamics. Matematicamente, um modelo System Dynamics é um sistema de equações lineares. Em geral, esse sistema é muito complexo para ser resolvido analiticamente e, portanto, utiliza-se a integração numérica. Por meio do Vensim, foi possível desenvolver, documentar, simular e analisar os modelos, verificando o impacto ambiental e social causado pela coleção nas sete linhas pesquisadas. Para a implementação no simulador Vensim (versão 2020), foram utilizados dados históricos para verificar a integração entre os módulos componentes do modelo, bem como os resultados gerados, uma vez que os outputs produzidos pelo modelo de simulação foram avaliados a partir de dados reais. fornecido a eles. Os resultados foram satisfatórios e atenderam às expectativas dos projetistas quanto à redução do impacto ambiental na transformação do Biodiesel em Diesel mineral.

Palavras-chave:. Biodiesel, Dinâmica de Sistemas, Emissão de CO_2 e Transporte Público.

Abstract: This work presents the understanding, development and execution of a computational model, whose main functionality is to analyze the quantity of CO2 emissions related to public transport without tariffs in the municipality of Maricá in the State of Rio de Janeiro, where three scenarios were generated with different percentages of Biodiesel added to mineral Diesel. For the development of the model, the System Dynamics method was used. Mathematically, a System Dynamics model is a system of linear equations. In general, this system is too complex to be solved analytically and, therefore, numerical integration is used. Through Vensim, it was possible to develop, document, simulate and analyze the models, verifying the environmental and social impact caused by the collection in the seven researched lines. As for the implementation in the Vensim simulator (version 2016), historical data were used to verify the integration between the component modules of the model, as well as the results generated, since the outputs produced by the simulation model were evaluated from real data. provided to them. The results were satisfactory and met the expectations of the designers regarding the reduction of the environmental impact in the increase of Biodiesel to mineral Diesel.

Keywords: Biodiesel, Systems Dynamics, CO_2 Emission and Public Transport.

1. INTRODUCTION

The activities of the tertiary sector in the economy have been playing a predominant role in the generation of jobs, causing a constant increase in the need for urban transport in cities, being essential to modern life, as it makes it possible for most residents to travel to carry out social activities. countries' economic and economic

In Brazil there are different modes for the transport of passengers such as the subway, BRTs (fast bus transport), trains, ferries, among others and each one with its operationality. Therefore, it is essential to know the subsystems of each transport mode in order to understand the impacts generated by physical, biotic and anthropic means in the different stages of the transport systems.

Transport, although indispensable, some affect the environment, considering that it depends on the use of a lot of energy, which results in the burning of fuels harmful to the environment, since most of the fuel burned is of fossil origin (MENDES, 2015). However, from an economic point of view, it is a service that does not create wealth, but helps to develop the productive potential of other activities, adding “time” and “space” to the mass. In addition, through public transport, people can move from one region to another, using a vehicle with a capacity for many passengers, optimizing the space and flow of traffic.

According to data from the National Energy Agency, the most widely used fossil fuel is oil, and in 2011 62% of the oil consumed worldwide was destined for the transport sector (D’AGOSTO, 2015). The bulletin of the National Agency of Petroleum, Natural Gas and Biofuels (ANP) published in June 2019, points out that in 2018 world oil consumption totaled 95 million barrels / day, with Brazil being the fifth largest consumer with approximately 3.2 million barrels / day (3.3% of the world total) (ANP, 2019).

Faced with this scenario, the country has been looking for alternatives to oil derivatives as the main source of energy for transport, since in 2016, according to data from the Ministry of Mines and Energy, it accounted for 30% of national energy consumption.

In this sense, biodiesel gains space in the market, being an option for its use in diesel engines. Such a practice would assist in decreasing the use of oil, and may be a solution to the dependence of many countries on the use of it (SOUZA et al. 2016). Brazil is the second largest producer of Biodiesel, and the industry expects to produce 4.5 billion liters in 2019, an increase of 20% compared to 2018 (OGLOBO, 2019).

One of the main justifications for the use of biodiesel in urban transport is due to the strategic substitution of petroleum products, in addition to reducing the net emissions of greenhouse gases, mainly CO possuir, and having a lower cost compared to oil (ANP, 2017) .

Public transport without tariffs in REGION, was conceived in 2014 and its full operation in 2017, after the delivery of the Viação Costa Leste concession, transported in the period of 1 year approximately 2 million passengers, between residents and visitors (EPTMARICA , 2019). With this, the City became the first in Latin America, with more than 100 thousand inhabitants, to provide public transportation without tariffs.

Given the above, this article aims to develop a model based on the dynamics of systems, capable of simulating the insertion of biodiesel in urban transport, analyzing the CO2 emission. This research is justified by the fact that Biodiesel is a fuel capable of reducing the impacts caused by the excessive use of fossil energy. Therefore, in addition to contributing to the dissemination of Biodiesel in the country, it is also intended to instigate the interest of academia and other sectors of society by knowing a little more about the subject.

Regarding the structure, this article is organized as follows: after this introductory part, then present the theoretical framework that supported this study, then describe the methods adopted in order to achieve the proposed objective. Following, there is the analysis and discussion of the results and ends with the conclusions from the study carried out accompanied by suggestions for future work.

2. THEORETICAL FRAMEWORK
2.1 ENERGY DEMAND

From the National Energy Balance, carried out by the Energy Research Company (EPE, 2020), it can be seen, in figure 2, the energy consumption matrix of the transport sector, elaborated based on the year 2019. The most efficient fuel used in Brazil in 2019 is diesel oil, with almost half of the total consumption (41.9%). Gasoline (25.3%) is the second most consumed fuel in the sector, followed by ethanol (20.6%).

The demand for electricity in Brazil more than doubled between 1990 and 2016 (Graph co19). The industrial segment is responsible for most of the electricity consumption in the country, accounting, in 2016, for 38% of the total consumption, followed by the residential segment, with 26%. The latter has been growing for the past ten years at an average rate of 4.5% per year (BEN, 2020).

In 2019, the total of anthropogenic emissions associated with the Brazilian energy matrix reached 419.9 million tons of carbon dioxide equivalent (Mt CO2-eq), the majority (193.4 Mt CO2-eq) being generated in the transport sector . In terms of emissions per inhabitant, each Brazilian, producing and consuming energy in 2019, emitted an average of 2.0 t CO2-eq, that is, about 1/7 of an American and 1/3 of a European citizen (European Union) or a Chinese according to the latest data released by the International Energy Agency (IEA in English) for the year 2017 (EPE, 2020).

For EPE (2020) the main source of emissions in the energy sector is transport: in 2018 they accounted for 200.2 million tons of CO2 and, or 49% of the total. Next are emissions from energy consumption in industry, with 61.8 MtCO2 and (15%), fuel production, with 54.5 MtCO2 and (13%) and electricity generation, with 48.7 MtCO2 and (12%). Transport emissions have historically been split fifty-fifty between cargo (104.4 Mt in 2018) and passengers (95.8 Mt).

For each toe made available, Brazil issues the equivalent of 74% of the European Union, 67% of the USA and 49% of China. The Brazilian electricity sector emitted, on average, only 90.0 kg CO2 to produce 1 MWh, a very low rate when comparing with countries in the Union, USA and China. Abrir no Google Tradutor • Feedback

2.2 BIODIESEL

Nas últimas décadas, pesquisas envolvendo fontes renováveis de energia destacaram-se mundialmente, das quais se podem citar as energias solar, eólica, hidroelétrica, geotérmica, das marés e aquelas derivadas da biomassa, incluindo o biogás e os biocombustíveis líquidos, dentre outros. Os biocombustíveis apresentam-se em diversas alternativas, das quais pode-se destacar no Brasil o uso do biodiesel, produzido a partir dos glicerídeos naturais, e o uso do etanol, produzido a partir da cana-de-açúcar.

The idea of using biodiesel as an alternative to its fossil equivalent already existed at the end of the 19th century. Rudolph Diesel, inventor of the engine that got his name, demonstrated at the Paris Exhibition in 1900, an engine running using peanut oil . Diesel wrote in 1912 that vegetable oils would, over time, become as important as oil and coal. What did not happen at that time due to the abundance of available oil (KLASS, 1998).

Klass (1998) indicates that many natural glycerides can be used with little or no difficulty as a fuel in indirect injection diesel engines, however they present major problems when used in direct injection engines. The transformation of fatty acids from natural glycerides into their corresponding esters, by means of transesterification reactions, in addition to mitigating the problems observed with natural glycerides, increase the performance of fuels, presenting higher flash points and reduced ash and sulfur content if compared to fossil diesel.

In Brazil, the use of biodiesel in mixtures with petroleum diesel is determined by Law No. 13.033 (2014), which also determines the responsibility for regulating the rates of mixing biodiesel with diesel for the National Petroleum Agency - ANP. The legal limits for mixing biodiesel, according to the law, vary from 6% (B6) to 15% (B15) of biodiesel added to fossil diesel. Currently, the percentage adopted is 13% (B13), according to ANP Resolution No. 798 (2019).

According to current legislation, biodiesel can be classified as any alternative fuel, of a renewable nature, that can offer socioenvironmental advantages when used in the total or partial replacement of petroleum diesel in internal compression ignition engines (diesel cycle engines). However, the only type of biodiesel regulated in the Brazilian territory corresponds to the alkyl esters derived from oils or fats of vegetable or animal origin (MENDES, 2015.).

Among the sources of biomass readily available, oils and fats of vegetable and animal origin have been widely investigated as candidates for renewable energy programs because they enable decentralized energy generation and strong support for family farming, creating better living conditions in needy regions. , valuing regional potentialities and offering alternatives to economic and socio-environmental problems that are difficult to solve. In Brazil, the National Program for the Production and Use of Biodiesel - PNPB, encourages the participation of family farmers in the biodiesel production chain, as biomass suppliers, especially soybeans, with around 96% participation and the remainder composed of : peanuts, canola, palm, sesame, sunflower, castor, coconut, macauba, fish oil, chicken oil, beef tallow, corn, cotton and buriti (MAPA, 2020).

More than an environmentally friendly alternative for developing countries like Brazil, the adoption of fuels derived from oils and fats in national energy matrices provides a considerable socioeconomic development niche for the region, since in addition to providing a new stimulus to the chains production of oilseeds, with the subsequent generation of millions of direct and indirect jobs, provides a gradual reduction in the levels of import of oil products, thus favoring the balance of trade deficits normally in deficit.

2.3 SYSTEM DYNAMICS

For Geum, Lee & Park (2014) systems dynamics is the combination of theories, methods and philosophies, aiming at analyzing the behavior of systems. For Bueno (2013), the system dynamics consists of a method developed for the analysis of the cause and effect relationships of certain variables of a system, be it organizational or social.

According to Bueno (2013) the addition of information causes actions (flows), changing the state (level) of a system, when a period of time has elapsed, generating two types of feedback cycles: the negative (or equilibrium) - in which the system reacts to changes, compensating for them; and the positive (or self-reinforcing) - in which the system amplifies possible disturbances.

or Vaz & Maldonado (2016), the main premise of the dynamics of systems refers to the importance of the structure of the system, that is, the physical elements, the decision rules and their interrelations, to explain the behavior of the system under study .

The second premise of systems dynamics, according to the authors mentioned above, is related to the system's responses to the actions of decision makers in the form of accumulation or reduction (of matter, energy or information).

On the other hand, as Vaz & Maldonado (2016) argue, the dynamics of systems assume that there are several stocks within socio-techno-economic systems, influencing each other through their flows and dynamically, this statement refers to the third premise of the dynamics of systems: the processes of feedback or feedback, that is, every action or decision eventually produces a reaction of the system, changing, therefore, the state of the system under study, being that the socio-techno- Economic factors are formed by more than one feedback loop, both positive and negative.

Finally, the fourth and last premise of systems dynamics, for Vaz & Maldonado (2016), concerns the effect of the time lag, or delay, that is, the existence of a gap between decisions and the respective results generated by them , dynamically influencing the system's behavior.

3. METHODOLOGY

The methodology used in this article is based on Systems Dynamics, allowing the study to create computational models to analyze the behavior of systems over time, thus allowing the evaluation of the consequences of our decisions. To apply the System Dynamics, computational modeling and scenario planning will be used.

Chwif and Medina (2015) describe computational modeling as a presentation of real systems, having great importance to understand the complexity of the real world. A simulation model is able to more accurately capture the characteristics of time, state and nature and from software these captured characteristics are repeated on a computer with the same behavior that the real system exhibits, thus helping in the decision-making process (CHWIF; MEDINA, 2015). According to Andrade et al. (2006), computational modeling is one of the tools of systemic thinking that adds learning to the process and through it, micro-worlds of the real system are built.

Scenario Planning promotes learning and challenges mental models by visualizing possible futures. With both methodologies acting together to feed the strategic process, there is a methodological contribution capable of offering the benefits described above in a synergistic way. In addition, it prevents the strategic process from suffering difficulties, such as the tendency to focus on events, the ineffective habit of seeking to predict the future, reactive behavior of adapting to the future and focusing only on problem solving (ANDRADE et al, 2006).

3.1 Steps of creating the model

Five steps were used to develop the research model. Step (I) represents the exploratory study in scientific articles, technical reports, dialogues with stakeholders and observations of the environment where the data were collected. It should be noted that the data were collected in a company in the Rio Grande do Sul region. Through this data, the research objective was specified and structured. Step (II) presents the development of the solution through the construction of formal models capable of representing the problem (definition of variables and their relationships).

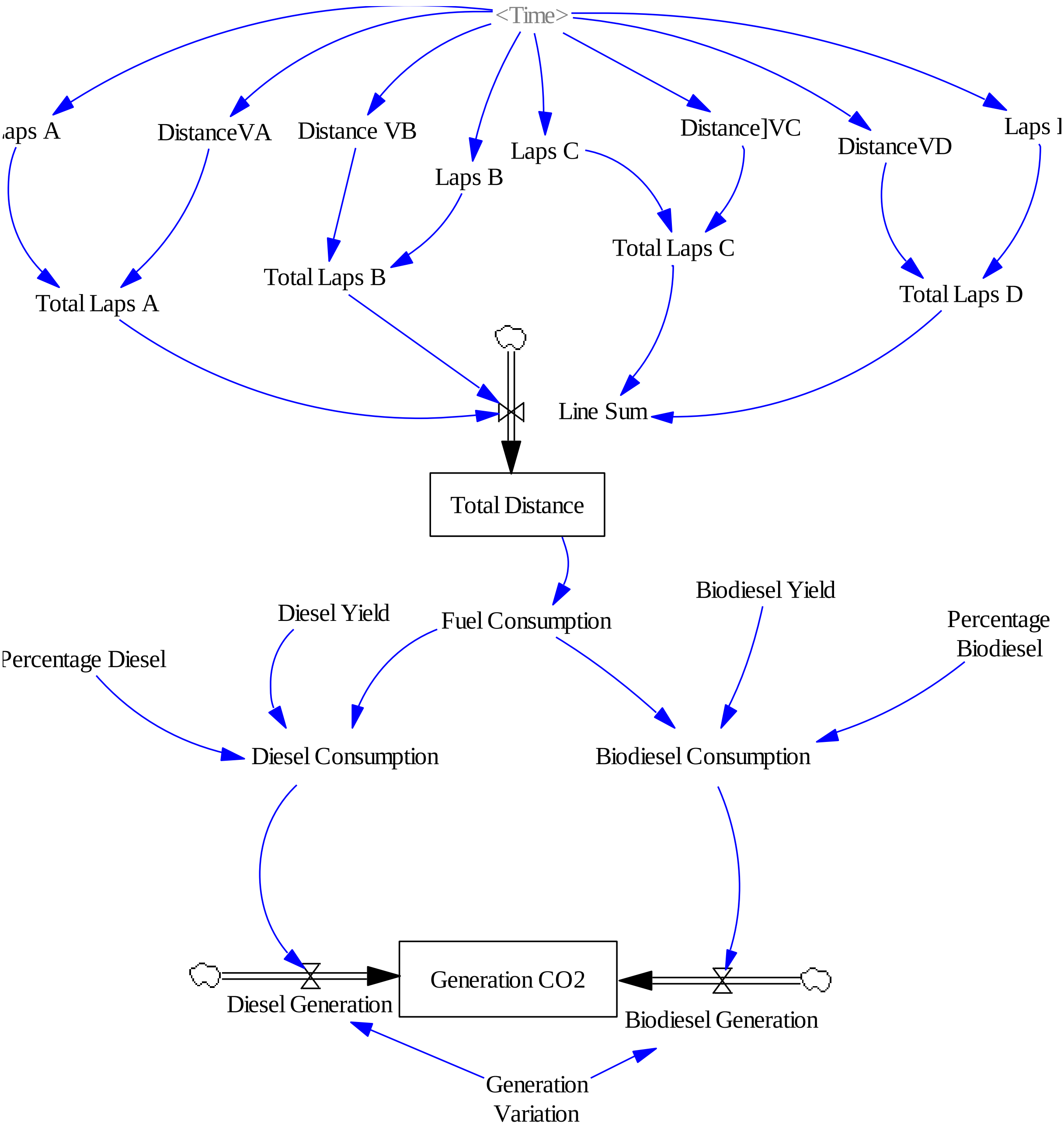
The computational implementation of the solution (step III) was carried out with the aid of the Vensim® simulator (VENTANA SYSTEMS, 2019) from the Systems Dynamics area. Stage (IV) is responsible for the verification and evaluation of the solution through laboratory tests and analysis of historical behavior (with the data that were possible) to verify whether the results obtained represent part of the observed reality, as well as through the simulation of an experiment adopting nine scenarios for this. In addition, managers from the areas involved were also interviewed to ensure greater reliability for the study. Finally, the research was analyzed in step (V) where the differences between the existing possibilities were exposed.

4. DEVELOPMENT OF THE COMPUTATIONAL MODEL

The worldwide consumption of oil products has taken an upward trend, driven by economic growth and modernization, especially in regions of economic development (RAZON; KNOTHE, 2017). In parallel to the increase in consumption is the emission of CO2, which has also been increasing in recent decades (CORDEIRO et al, 2017). In this context, this article has developed a computational model that could be a solution for the use of a cleaner and cleaner fuel. with less environmental impact. It will enable urban transport managers to make the best decision when choosing a cleaner fuel.

The model shown in figure 1 is responsible for storing urban transport data, enabling the monthly routine of urban transport routes in the explored city to be transferred to the computational environment. Despite having a city as a parameter, the model can be applied to any region, since one of the goals of modeling is to develop models to be applied in any circumstance. The model will analyze the generation of carbon dioxide by the urban transport of the city studied.

Figure 1. Developed Model



Source: Authors (2021)

The computational model developed is based on the interaction between auxiliary variables, flows and stocks. Initially, four auxiliary variables responsible for inserting the behavior of the transport lines were generated: "Laps A", "Laps B", "Laps C" and "Laps D". Each variable represents a region of the studied municipality. The auxiliary variables

"DistanceVA", "DistanceVB", "DistanceVC" and "DistanceVD" store the distance, in kilometers, of each turn. In order to verify the distance traveled monthly by all buses, auxiliary variables “TotalLapsA”, “TotalLapsB”, “TotalLapsC” and “TotalLapsD” were generated. These variables will serve as input value for the “TotalDistance” stock flow, which in turn will store the distance traveled by the buses monthly. The shadow variable “time” will insert the variations of all components of this model, it is through it that the calculation of the distance covered in periods with less passengers is inserted.

The auxiliary variable “FuelConsumption” receives the output value from the stock “TotalDistance”. In this part of the model the fuel consumption of the transport is calculated. The variables “PorcentageDiesel” and “PorcentageBiodiesel” help the scenarios in dividing the quantity of diesel and biodiesel per liter. The calculation of the consumption of each fuel is stored in the variables "DieselConsumption" and "BiodieselConsumption", through the interaction of the auxiliaries "PorcentageDiesel", "PorcentageBiodiesel", DieselYield "," BiodieseYieldl ", and" FuelConsumption ".

The analysis of the model will be stored in the “GenerationCO2” stock variable, where the CO2 generation will be exposed by the planned scenario. The stock inflows are “DieselGeneration” and “BiodieselGeneration” where the consumption of each fuel is stored. The auxiliary variable “GenerationVariation” will store the average generation behavior for the fuel used in transportation.

4.1 DEVELOPED SCENARIOS

To build scenarios, one must first define the central decision to be made, the problem or situation of interest to be evaluated. Then, it is necessary to identify the main driving forces, which, according to Schwartz (2000), are those forces that act structurally in reality and that are important for (and impact on) the decisions of individuals and the consequences of decisions in the future . The driving forces are of two types: (1) predetermined elements (or trends), which are forces on which, from a structural point of view, one has a very clear vision of how they will unfold in the future; and (2) critical uncertainties, which are forces for which we do not have a very clear idea about their future developments. In this study, the scenarios will be responsible for dividing the amount of biodiesel and diesel. Each scenario will present a variation of diesel and biodiesel, the idea is to reduce the amount of diesel to check the environmental impact. The scenarios are presented in the Frame 1 below.

Frame 1. Scenarios

	Biodiesel (%)	**Diesel(%)**

Scenario A	8	92
Scenario B	15	85
Scenario C	20	80

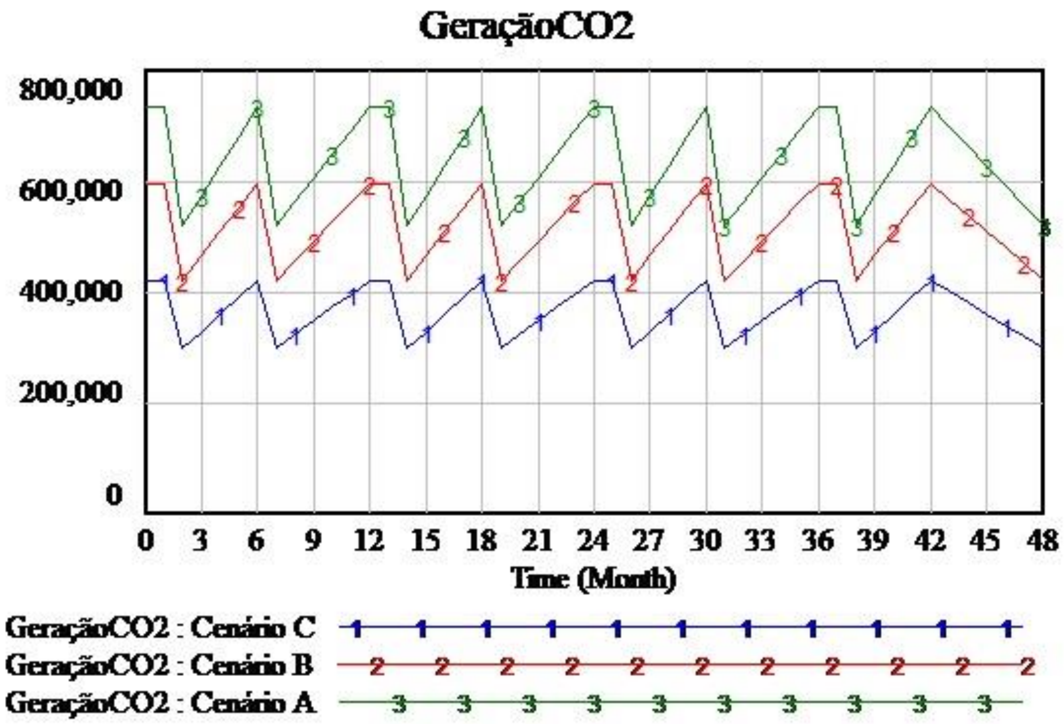
Source: Authors (2021)

Scenario A is responsible for storing the logic of the current behavior of the fuel used in urban transport companies, whereas scenarios B and C are the study's proposals. The scenarios can present other divisions, it is up to the decision maker to create his own logic. In the case under analysis, some results can be verified, such as the amount of fuel used, variation of kilometers traveled per route or total, in addition to the amount of CO2 emissions generated. Next, this last note will be explored.

5. EXPERIMENT AND ANALYSIS OF RESULTS

Having defined the three scenarios, it became possible to simulate the model proposal developed in the Vensim® simulator (VENTANA SYSTEMS, 2019). The simulated time horizon in the experiment was ten years (from 2019 to 2029), however, the configuration of this variable is left to the designer / user, as it depends on the analysis to be made. With the model developed, several analyzes can be performed and in the current study the analysis of CO2 emissions was selected.

Graphic 1.Geração CO2



Source: Modeling result

Ao realizar a modelagem foi verificada a confiabilidade do modelo, observando as relações entre as variáveis para que não viole nenhum pressuposto teórico. O resultado apresenta um ajustamento significativo das variáveis com a série histórica de janeiro de 48 meses, tendo em vista que não há discrepâncias.

The current scenario (A) presented by line 1 (green) shows a variation of consumption of 520,115 kilograms of CO geração generation, the scenario (B) presented by the red line, generates a production of 421,173 kilograms up to 595,530 kilograms emitted in the air, the scenario (C) represented by the blue line reduces CO geração generation compared to scenario (A) by 42.80% where they move below the curve of the previous scenario with the inclusion of 20% Biodiesel in the timeline between 10 years designed. The results show that in the scenario that uses 25% biodiesel there is a reduction in CO emissão emission by up to 59.55%; from 735,432 to 297,495 kilograms emitted in the air, showing a great decrease in air pollutants.

6. CONCLUSION

The main objective in this research was the development of verification, and the experiment of a computer simulation model to assess the amount of CO2 emissions related to public transport. Thus, the contribution was to deliver a model that can be applied to urban transport companies that use diesel in their transport vehicles. It was proposed to achieve the objective, the use of Biodiesel in different percentages, making it possible to analyze the difference in generation of each mixture with the current fuel.For the development of the simulation model, the concept that Systems Dynamics models composed of variables of stock, flow, auxiliary variables and connectors was taken into account. One of the central objectives of this methodology is to have a model that can simulate real behavior, that is, that the source of problems in a system is an inherent part of the model developed.

In this way, the Systems Dynamics methodology helped to map the structures of the developed system, seeking to examine its interrelation in a broad context. Through this simulation, the applied dynamics sought to understand how the system in focus evolved over time and how changes in its parts affect its behavior. From this understanding, it was possible to diagnose and predict the system, in addition to making it possible to simulate more scenarios over time.

Three scenarios were generated, using data collected directly from the company responsible for transporting the region and also through bibliographic review. The results obtained were consistent with the reality and the rates used were developed by the designers of the model to carry out this study. It is worth mentioning that the scenarios were generated for this experiment, however the model can be configured according to the needs of those who will use it, that is, it is a reconfigurable and open model.

The results presented were obtained through simulations made using the Vensim software. It was observed that the reductions in the financial impact generated for a scenario of 48 months justify the application of the results generated by the model. Therefore, based on the results generated by the simulation, managers will be able to define paper purchasing policies taking into account environmental sustainability in the decision-making process. As future work, it is intended to expand the model to other companies and, also, to consider in the evaluation the social benefits that can be generated, such as job creation.

REFERENCES

ANP. Agência Nacional do Petróleo, Gás Natural e Biocombustíveis. Boletim Anual de Preços 2019: preços do petróleo, gás natural e combustíveis nos mercados nacional e internacional/ Agência Nacional do Petróleo, Gás Natural e Biocombustíveis. Rio de Janeiro: 155 p.: il. color., gráficos, tabelas.

BARCZAK, R,D,F. "*Impactos Ambientais Da Mobilidade Urbana: Cinco Categorias de Medidas Mitigadoras*". Revista Brasileira de Gestão Urbana. Ed. 4. 2017.

BUENO, N. P . *Identificando mudanças de regimes sistêmicos em processos econômicos: um procedimento baseado na abordagem de dinâmica de sistemas*. Economia e Sociedade, 22(1), 77-106, 2013.

CATS, ODED., REIMAL, TRIIN.,SUSILO, YUSAK..“*Public Transport Pricing Policy - Empirical Evidence from a Fare-Free Scheme in Tallin, Estonia”.* Transportation Research Board, 93rd Annual Meeting 2415: 89–96. http://trrjournalonline.trb.org/doi/abs/10.3141/2415-10, 2014.

CAMPOS, V.B.G. “Uma Visão da Mobilidade Urbana Sustentável”, 2003.

CONFEDERAÇÃO NACIONAL DE TRANSPORTE. *Sondagem CNT de Eficiência Energética no Transporte Rodoviário de Cargas.* Brasília, 2015. Disponível em: <file:///C:/Users/Lucas/Downloads/Sondagem_2015_web%20(2).pdf>. Acesso em: 26 set. 2019.

DA SILVA, F. Royalties do Petróleo e Eleições Municipais: O Caso Brasileiro ", Anais do XLI Encontro Nacional de Economia [Anais do 41º Encontro Brasileiro de Economia] 078, ANPEC - Associação Nacional dos Centros de Pós-Graduação em Economia, 2014. Disponível em: <https://ideas.repec.org/p/anp/en2013/078.html>. Acesso em 30 set. 2019.

DE CARVALHO, C.H.R. *Emissões Relativas de poluentes do Transporte Motorizado de Passageiros nos Grandes Centros Urbanos Brasileiros*. Instituto de Pesquisa Econômica Aplicada (IPEA). Brasília, 2011. Disponível em: <https://www.econstor.eu/bitstream/10419/91332/1/664398472.pdf>. Acesso em: 27 set. 2019.

EMPRESA PÚBLICA DE TRANSPORTES DE MARICÁ (EPT).*Tarifa Zero - Vermelhinhos*. Disponível em: <http://www.eptmarica.rj.gov.br/empresa/projeto1.html>. Acesso em 30 set.2019.

FEARNLEY N.. *Free fares policies: impact on public transport mode share and other transport policy goals*. Int J Transp,2013.

FLAMM, M.,. *Comprendre le choix modal—les de´terminants despratiques modales et des repre´sentations individuelles des moyens de transport (Unpublished Ph.D.).* EPFL, Lausanne, 2004

GEUM, Y. LEE, S., ; PARK, Y . *Combining technology roadmap and system dynamics simulation to support scenario-planning: a case of carsharing service.* Computers & Industrial Engineering, 71, 37-49, 2014,.

GOLDEMBERG, J.; LUCON, O. *Energia, Meio Ambiente e Desenvolvimento*. 3. ed. São Paulo: Editora da Universidade de São Paulo, 2011.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE).Cidades: Maricá. Disponível em: <https://cidades.ibge.gov.br/brasil/rj/marica/panorama>. Acesso em: 30 set. 2019.

KĘBŁOWSKI, W.. “*Why (Not) Abolish Fares? Exploring the Global Geography of Fare-Free Public Transport*”. Transportation (0123456789). https://doi.org/10.1007/s11116-019-09986-6, 2019.

MENDES, P.A.S. Sustentabilidade na produção e uso do biodiesel. Curitiba. Annris. 2015.
TAKAMOTO, Walter. *Tarifa,Mobilidade e Exclusão Socia*l. São Paulo: Fundação Perseu Abramo, 2014.

VAZ, C. R.; MALDONADO, M. U (2016). *O que é a Dinâmica de Sistemas? Reflexões sobre sua evolução e sobre as oportunidades de aplicação na gestão de operações*, disponivel em https://www.researchgate.net/publication/305222914_O_que_e_a_Dinamica_de_Sistemas_Reflexoes_sobre_sua_evolucao_e_sobre_as_oportunidades_de_aplicacao_na_gestao_de_operacoes , (acesso em 29 mar. 2020), 2016.
Biodiesel: Matérias-Primas, Tecnologias de Produção e Propriedades Combustíveis Ramos, L. P.;* Kothe, V.; César-Oliveira. M. A. F.; Muniz-Wypych, A. S.; Nakagaki, S.; Krieger, N.; Wypych, F.; Cordeiro, C. S. Rev. Virtual Quim., 2017, 9 (1), 317-369, 2016

BEN. Balanço Energético Nacional 2020. Disponível em: https://www.epe.gov.br/pt/publicacoes-dados-abertos/publicacoes/balanco-energetico-nacional-2020.

EMPRESA DE PESQUISA ENERGÉTICA. Relatório energético, ano base 2016.Disponível em https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-479/topico-521/Relato%CC%81rio%20Si%CC%81ntese%20BEN%202020-ab%202019_Final.pdf>.